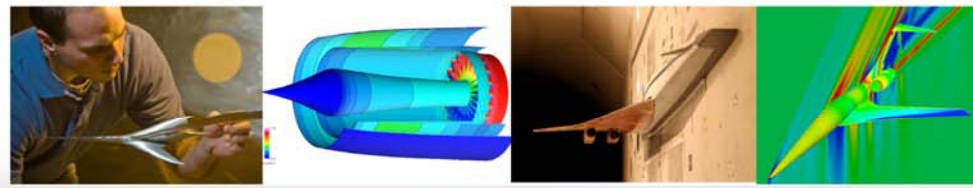
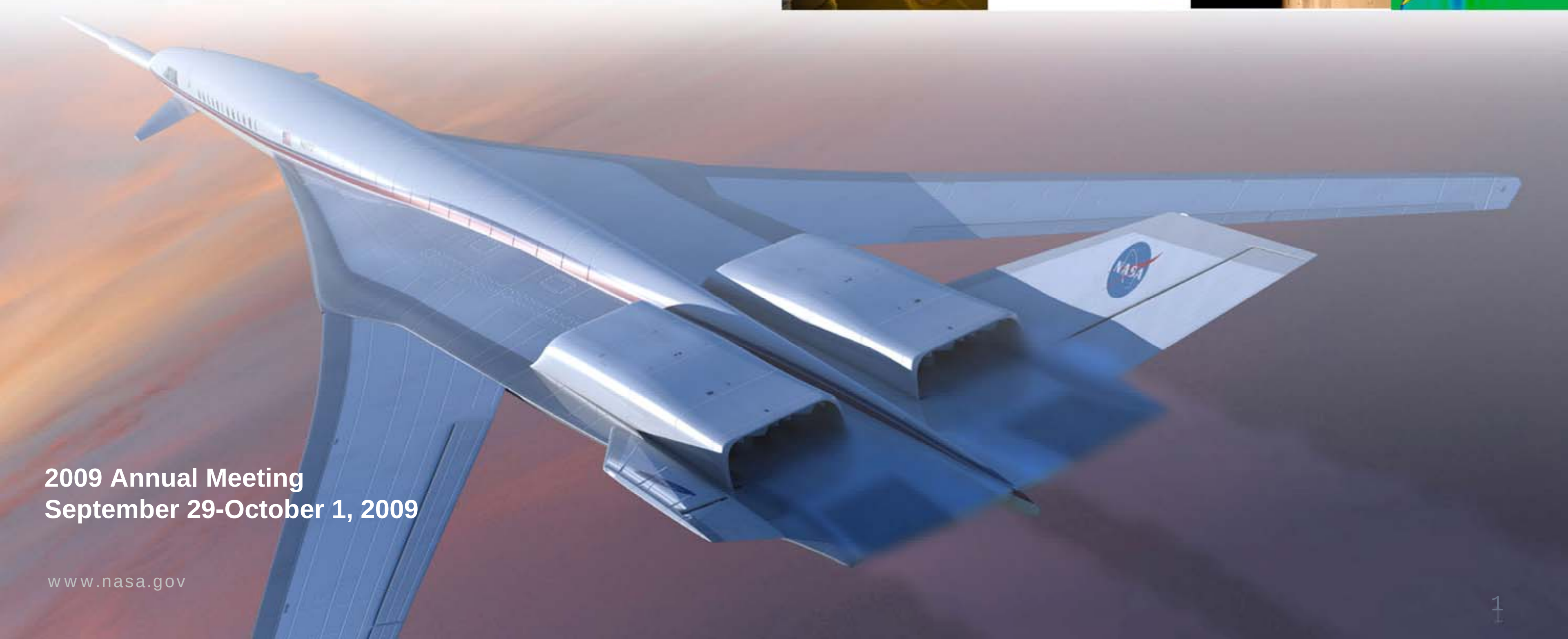
NASA Fundamental Aeronautics Program
Supersonics Project

Peter Coen
Principal Investigator

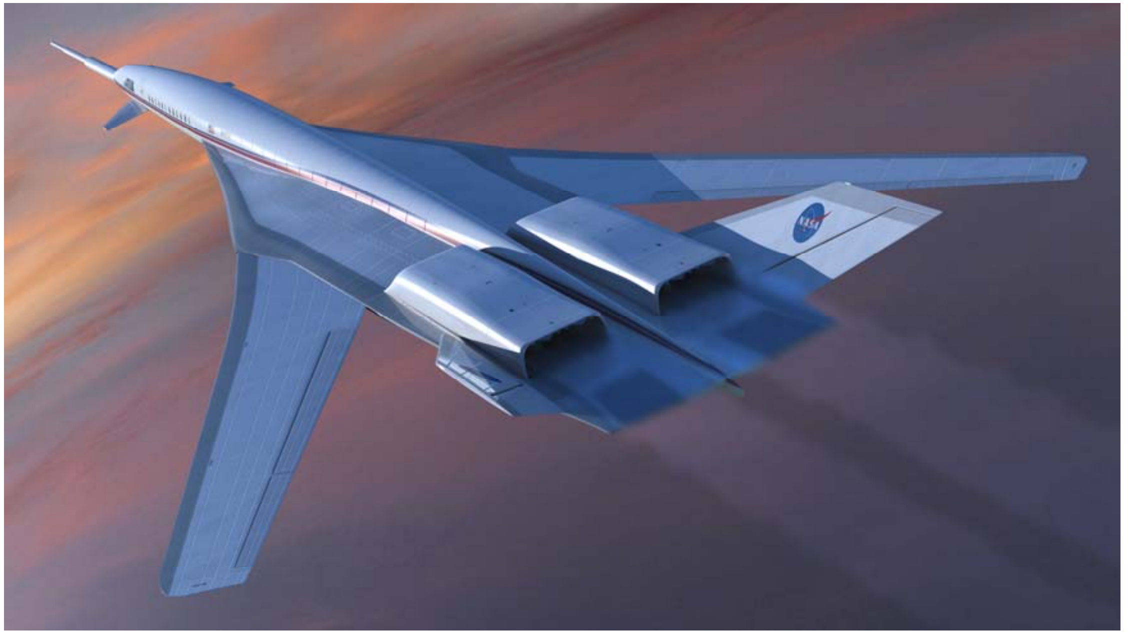




2009 Annual Meeting
September 29-October 1, 2009

Fundamental Aeronautics Supersonics Project

Project Goal: Tool and technology development for the broad spectrum of supersonic flight.



Supersonic Cruise Aircraft

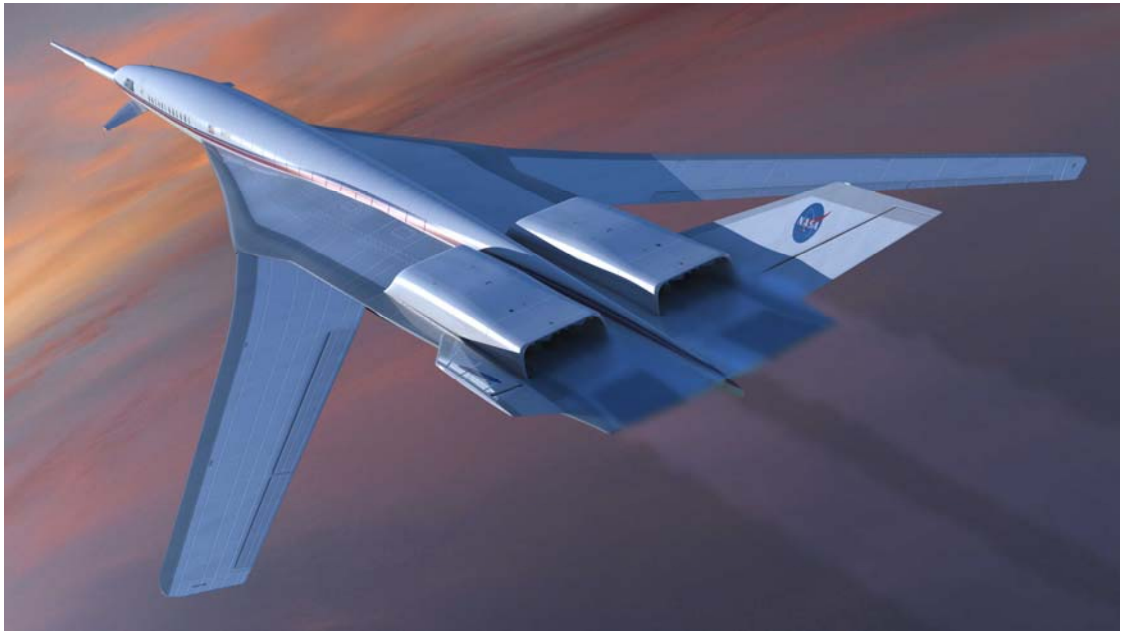
Eliminate the efficiency, environmental and performance barriers to practical supersonic cruise vehicles

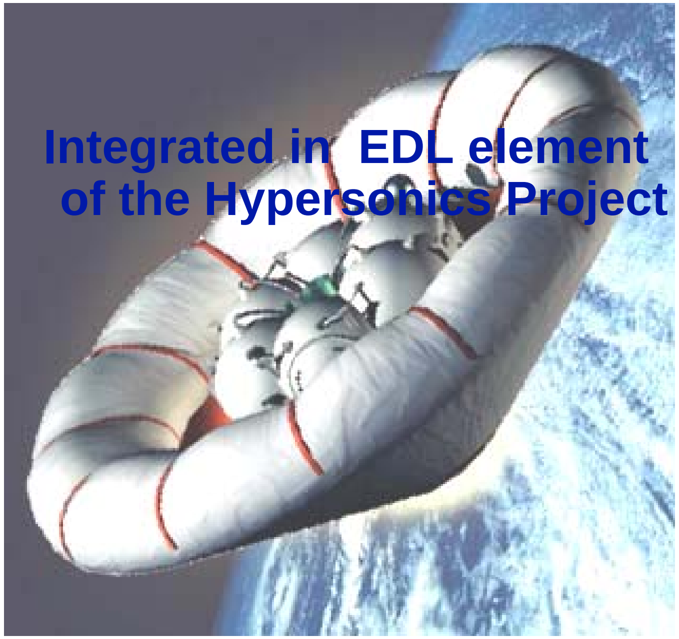
High Mass Planetary Entry Systems

Address the critical supersonic deceleration phase of future large payload Exploration and Science Missions

Fundamental Aeronautics Supersonics Project

Project Goal: Tool and technology development for the broad spectrum of supersonic flight.





FY 2010 and Beyond

- Supersonic project single focus area: Supersonic civil aircraft
- Near term emphasis on achieving supersonic overland cruise
- Supersonic decelerator research integrated into EDL element of the Hypersonics Project

Supersonics Project Technical Challenges

The Supersonics technical challenge areas are designed to break the traditional discipline "stovepipes" and foster innovative solutions "at the seams" between disciplines

- **Efficiency Challenges - 30 % Improvement over HSR**
  - Supersonic Cruise Efficiency
  - Light Weight and Durability at High Temperature
- **Environmental Challenges - No greater impact than subsonic fleet**
  - <u>Airport Noise</u>: Acceptable levels without weight or performance penalty
  - <u>Sonic Boom</u>: Propagation, prediction and design
  - <u>High Altitude Emissions</u>: Emissions impact must be minimized or eliminated
- **Performance Challenges - Safe and comfortable flight for crew and passengers**
  - <u>Aero-Propulso-Servo-Elastic (APSE) Analysis and Design</u>: Controlling flutter, gust, and maneuver loads in a manner that is synergistic with the vehicle structural design
- **Entry Descent and Landing Challenges**
  - <u>Supersonic Entry Deceleration:</u> Develop tools and technologies to support the design and validation of exploration systems capable of landing payloads in the 30 metric ton class
- **System Integration, MDAO Challenges**
  - Understanding and exploiting the interactions of all these supersonic technology challenges is the key to the creation of practical designs
- **Integration of Supersonic Aircraft in NextGen System**
  - Determine the characteristics for an airspace that enables supersonic aircraft to utilize their full capabilities

Supersonic Project Technical Elements – Part 1

Cruise Efficiency
- Tools and technologies for integrated propulsion and vehicle systems level analysis and design
- High performance propulsion components
- Low Boom / Low Drag design

Airport Noise
- Improved supersonic jet noise models validated on innovative nozzle concepts

Sonic Boom Modeling
- Realistic propagation models
- Indoor transmission and response models

Aero-Propulso-Servo-Elasticity
- ASE/flight dynamic and propulsion analysis and design tool development and validation
- APSE analysis and design tools

High Altitude Emissions
- Improved prediction tools
- Low emissions combustors

Light Weight and Durability at High Temperature
- Materials, test and analysis methods for airframe and engine efficiency, durability and damage tolerance

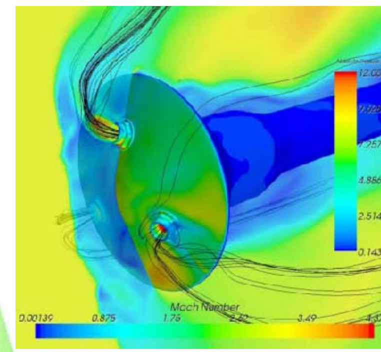
Supersonics Project Technical Elements - Part 2

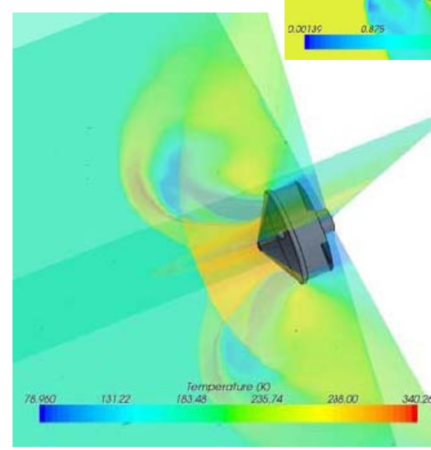
Inflatable Aerodynamic Decelerators

- Develop Architectures
- Evaluate Performance
- Predict Fluid – Structure Interaction

Supersonic Retro-Propulsive Decelerators

- Develop Architectures
- Evaluate Performance
- Predict Fluid – Fluid Interaction





Becomes Atmospheric Decelerator Technologies in the Hypersonics Project

Overview Presentation Thursday afternoon

Organization and Key Personnel FY10

* New in 2009

Supersonics Project Leadership Team

Principal Investigator (PI)
Peter Coen

Project Scientist (PS)
Louis Povinelli

Project Manager (PM)
Kestutis Civinskas

Business Support
Mary Neuzil: Business Team Lead
Tom Wallet: NRA Manager*

Technical Challenge Working Groups / APIs

Cruise Efficiency - Propulsion
Jim DeBonis

Cruise Efficiency - Airframe
Linda Bangert

Systems Integration & Assessment
Lori Ozoroski & Clayton Meyers

Lightweight & Durable Engines
Dale Hopkins

Lightweight & Durable Airframes
Phil Bogert

Entry, Descent, & Landing
Chuck Player **Moves to Hypersonics**

Airport Noise
James Bridges

Sonic Boom Modeling
Alexandra Loubeau *

Exp. Validations & Capabilities
Dan Banks

High Altitude Emissions
Dan Bulzan

Aero-Propulso-Servo-Elasticity
Walt Silva

APMs

- Clayton Meyers / GRC
- David Richwine / LaRC
- Don Durston / ARC
- Tim Moes / DFRC

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~~**Entry, Descent & Landing**~~
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Airport Noise
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Alexandra Loubeau *

Flight Research and Validation
Dan Banks

High Altitude Emissions
Dan Bulzan

Aero-Propulso-Servo-Elasticity
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APMs

Clayton Meyers / GRC
David Richwine / LaRC
Don Durston / ARC
Kevin Walsh/ DFRC

NASA Supersonic Transport Systems Level Metrics

	N+1 Supersonic Business Class Aircraft (2015)	N+2 Small Supersonic Airliner (2020)	N+3 Efficient Multi-Mach Aircraft (Beyond 2030)
Environmental Goals			
Sonic Boom	**65-70 PLdB**	**65-70 PldB**	**65-70 PLdB Low Boom flight 75-80 PldB Overwater flight**
Airport Noise (cum below stage 4)	**Meet with Margin**	**10 EPNdB**	**10-20 EPNdB**
Cruise Emissions (Cruise NOx g/kg of fuel)	**Equivalent to current Subsonic**	**< 10**	**< 5 & particulate and water vapor mitigation**
Performance Goals			
Cruise Speed	**Mach 1.6-1.8**	**Mach 1.6 -1.8**	**Mach 1.3 - 2.0**
Range (n.mi.)	**4000**	**4000**	**4000 - 5500**
Payload (passengers)	**6-20**	**35-70**	**100 - 200**
Fuel Efficiency (pass-miles per lb of fuel)	**1.0**	**3.0**	**3.5 Š 4.5**

N+1 “Conventional”

N+2 Small Supersonic Airliner

N+3 Efficient, Multi Mach Aircraft

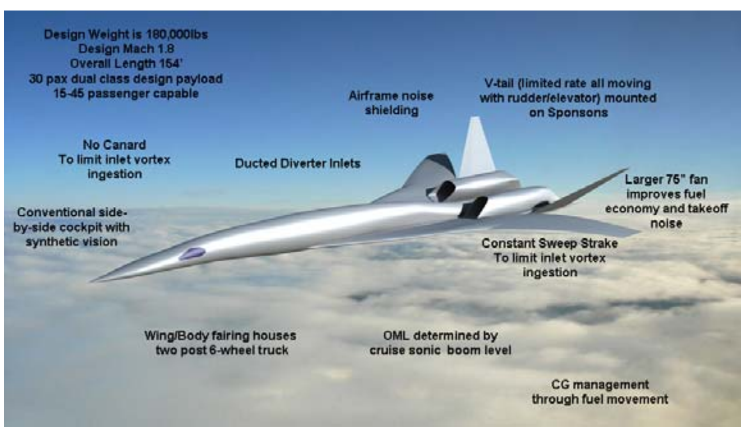
Supersonic Concept Development & System Analysis

- Objectives
  - Refine NASA's vision of system level metrics
  - Develop innovative configurations for technology integration and validation
  - Define technology requirements, benefits & roadmaps
  - Explore trade space with evolving MDAO capabilities

N+2 Completed by Boeing Team 6/09

Technical Specs:

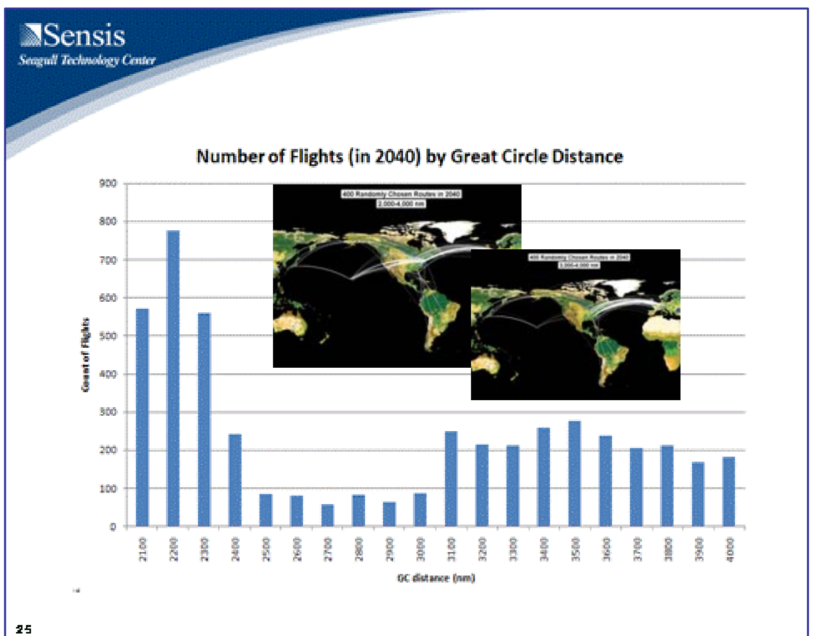
- 180,000 lbs design TOGW
- Mach 1.8
- Overall Length 154ft
- 30 passengers dual class
- Boom softened
- Advanced MFTF engine
- Stage 3 -15EPNdB

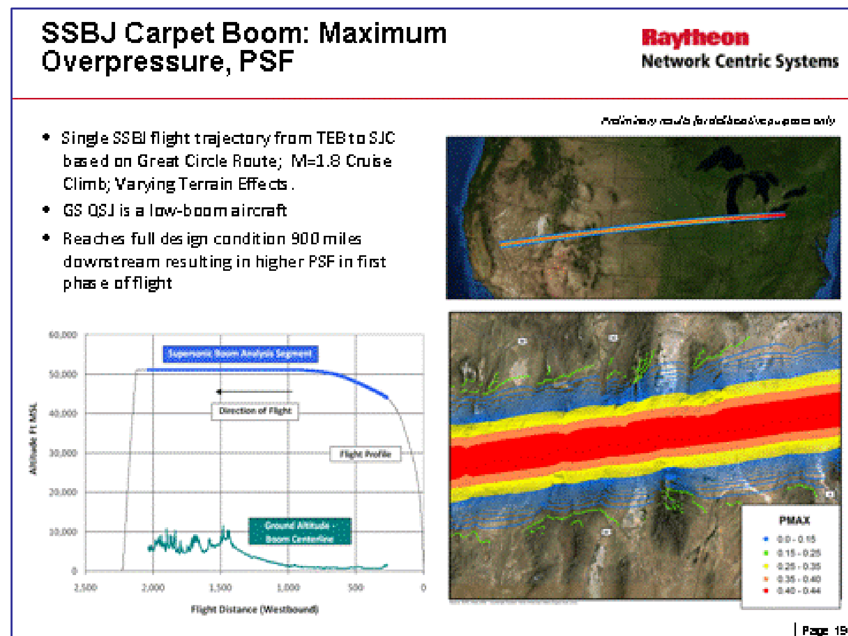


N+3 Awarded to Boeing & Lockheed Teams 9/09

Supersonic Aircraft in the NextGen Airspace System

- Collaborative effort with Airspace Systems Program funded NRA
- Investigating airspace traffic and terminal operation impacts relating to two classes of commercial supersonic aircraft in the 2025 and 2040 Joint Program Development Office (JPDO) projected marketplace.
  - Raytheon (Gulfstream, et al.) ~10pax Supersonic Business Jet N+1
  - Sensis Corp. (Georgia Tech, Boeing N+2 team, et al.) 100pax Small Supersonic Airliner, N+2
- Investigations include sonic boom ground tracks, flight frequency and city pair traffic, departure and arrival metering with subsonic aircraft patterns



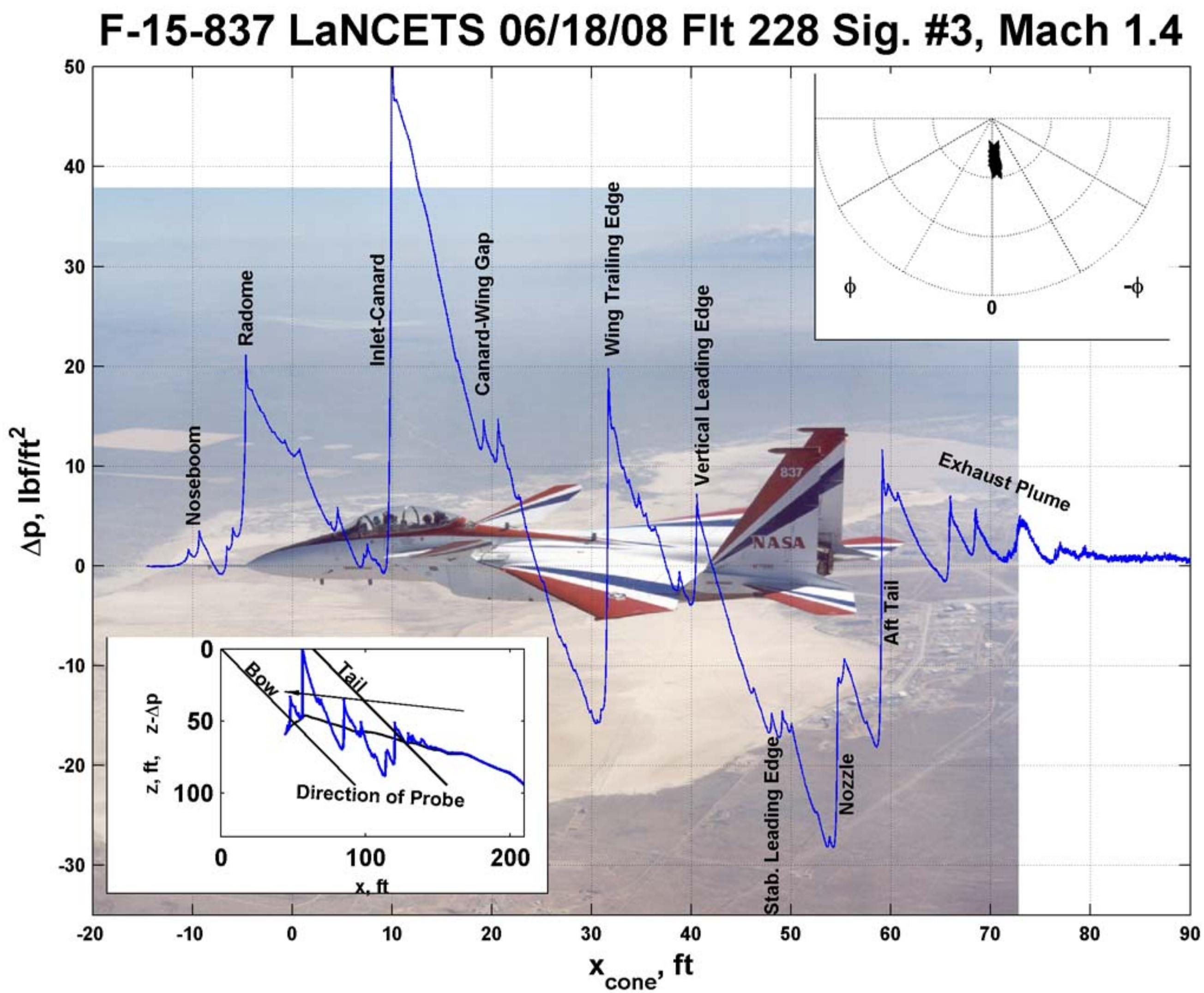


Look for presentations at 2pm and 4pm today in NextGen parallel session

FY 09 Technical Accomplishments

Another Great Year!

FY 09 Technical Accomplishments



FY 09 Technical Accomplishments

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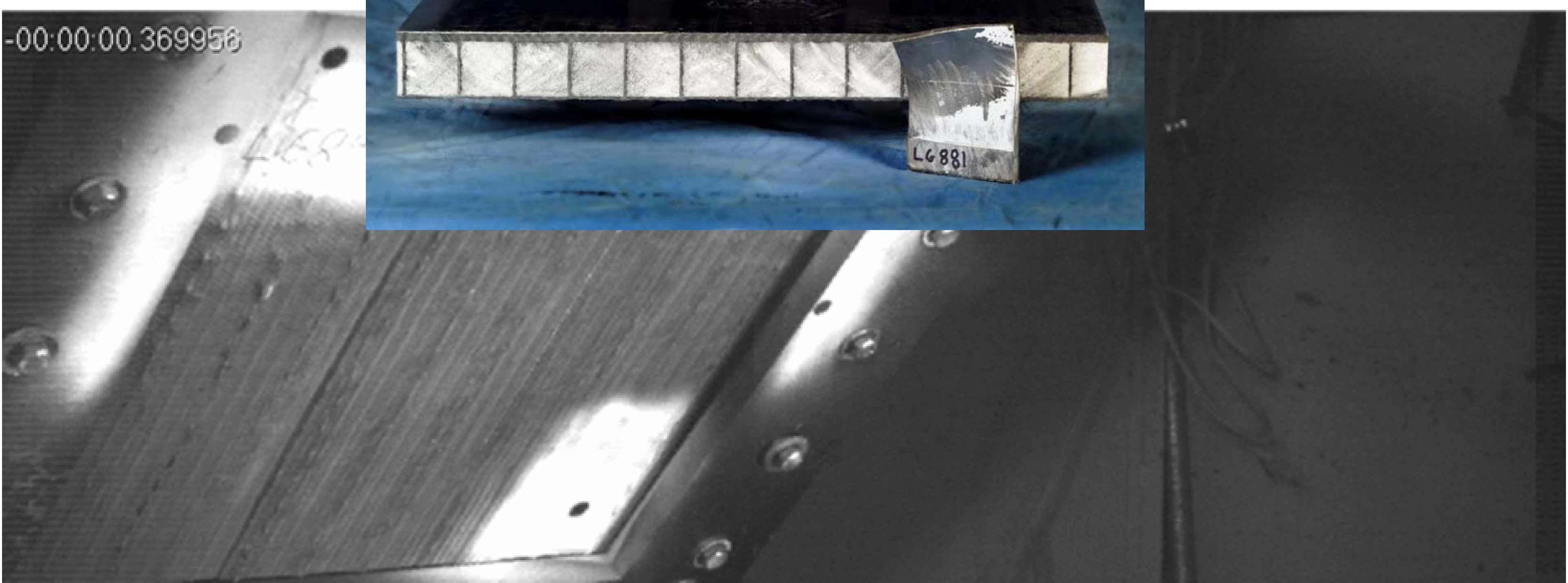

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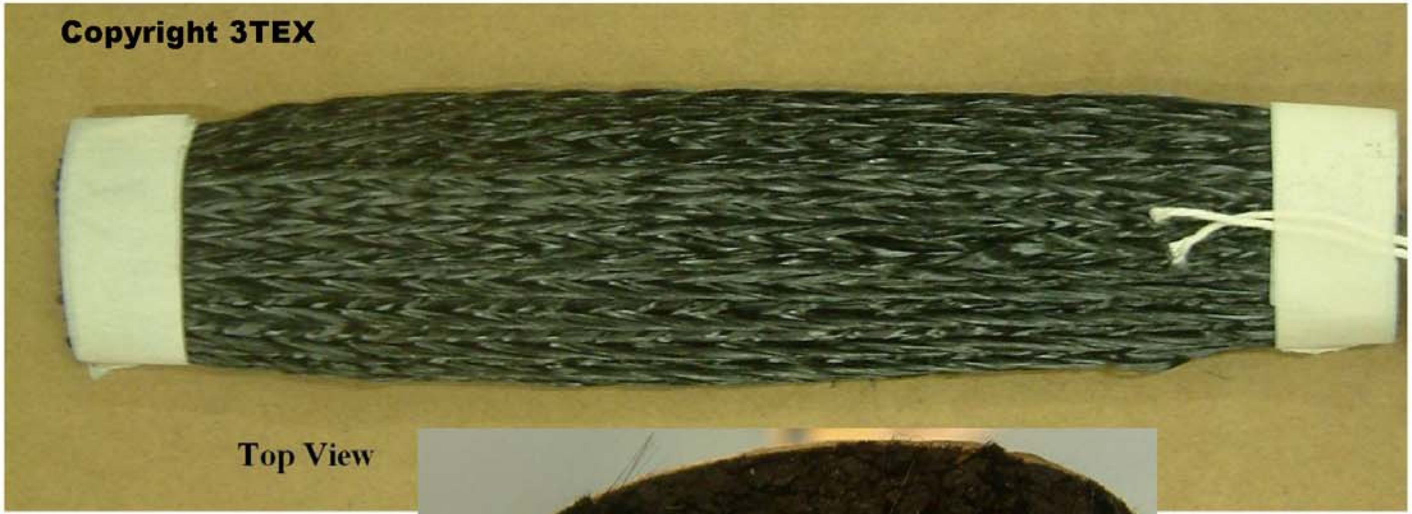
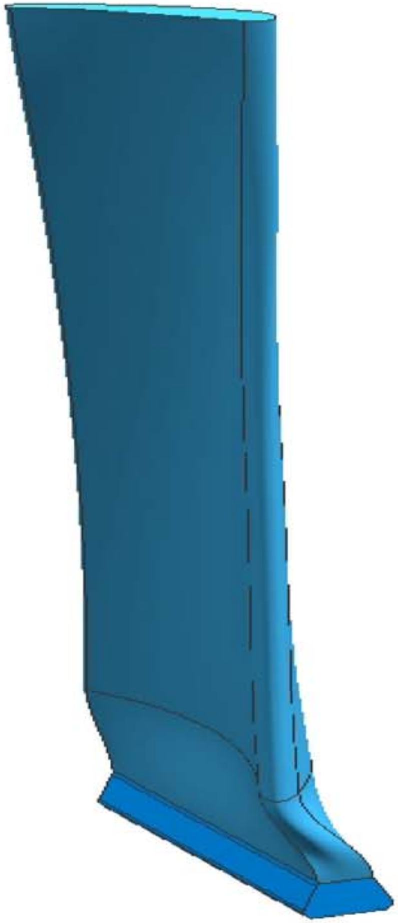




FY 09 Technical Accomplishments

Multi-Fidelity Aft-Shaping Methods for Design of Low-Boom Supersonic Concepts

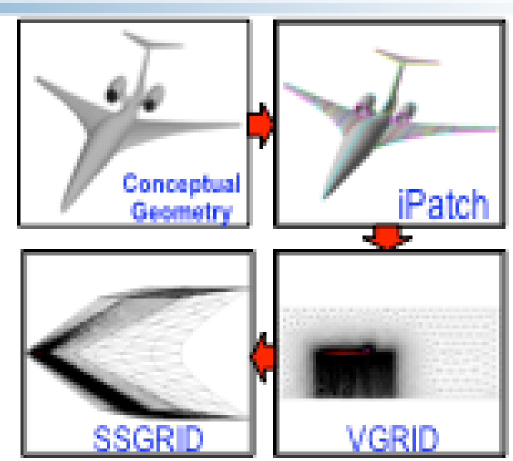
Milestone SUP.02.03.006

Integrated Multi-fidelity Aft End Vehicle Shaping Methodology Developed.

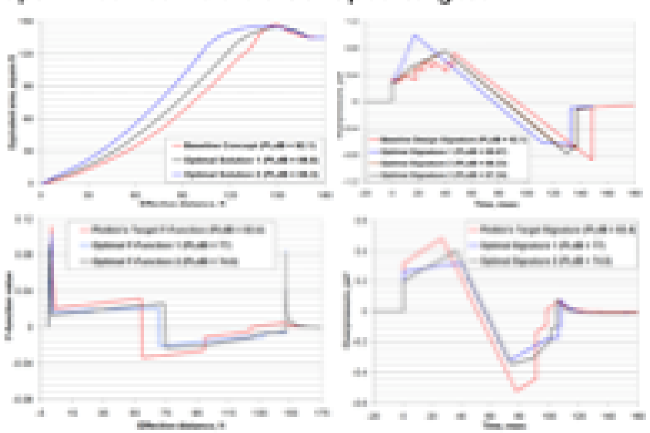
Exit Criteria

Demonstrate integrated multi-fidelity aft shaping design methodology in ModelCenter. This capability shall include:

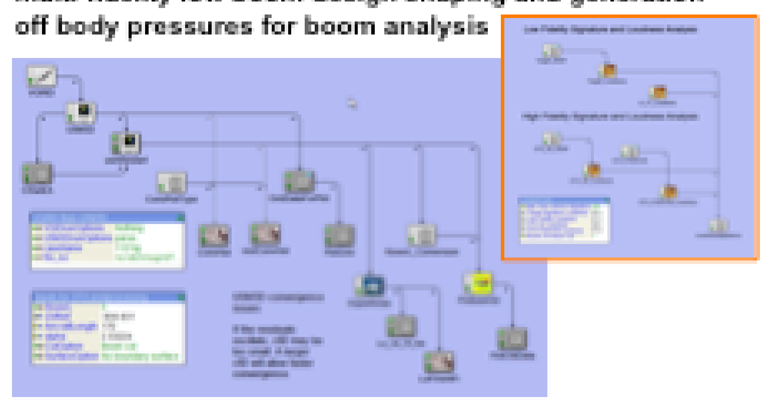
- Ability to generate non-classical SEEB low boom target area distributions for improved aft shaping targets.
- Aft lift and plume simulation in low fidelity shaping process.
- CFD (USM3D) generated lift in multi-fidelity low boom shaping.



Multiple approaches are now available for generating optimized realizable aft shaped targets



Integration of automated CFD (USM3D) generated lift for multi-fidelity low boom design shaping and generation off body pressures for boom analysis



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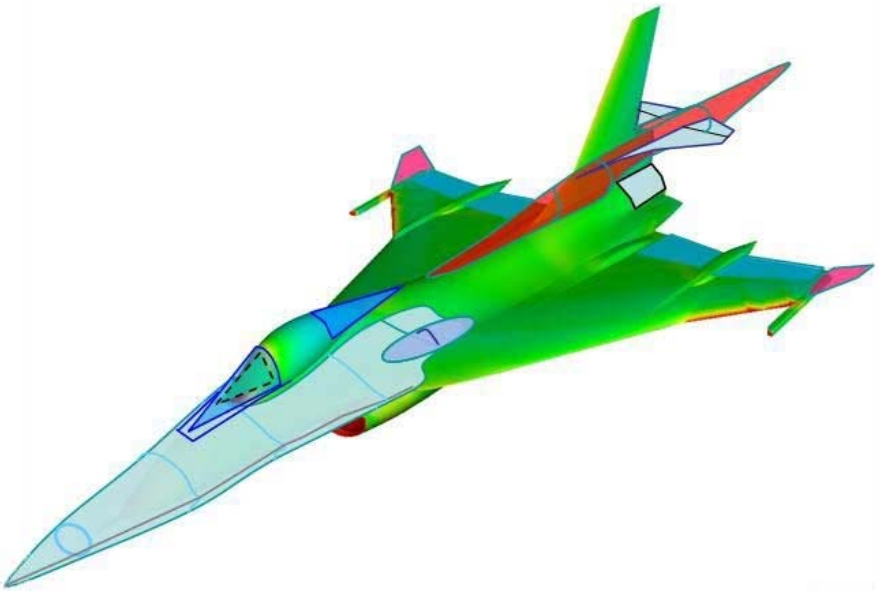
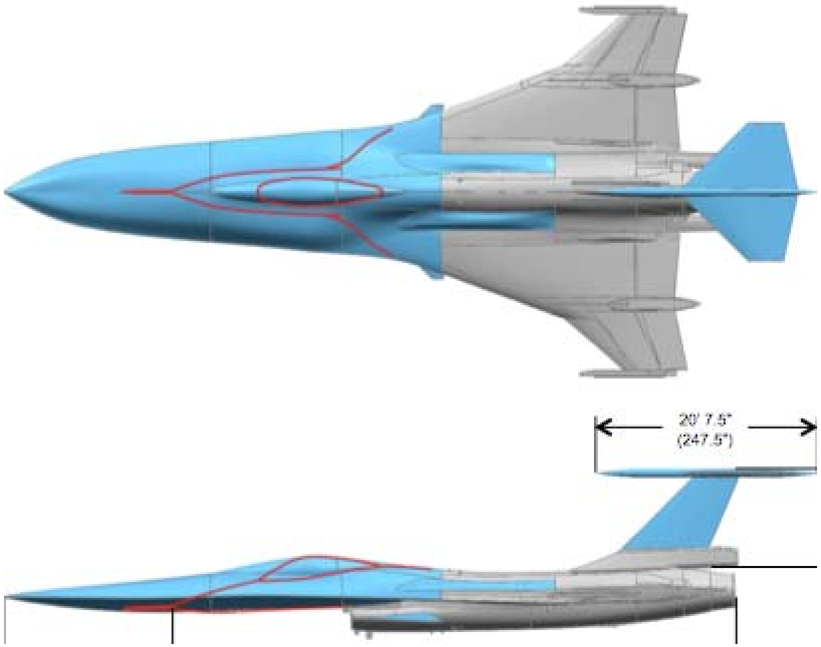
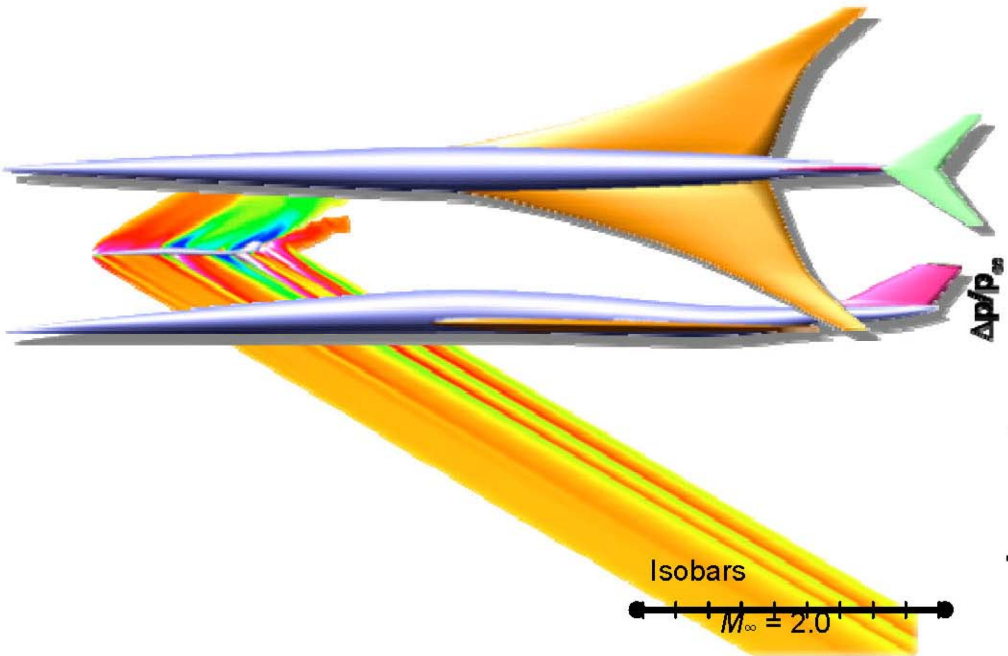


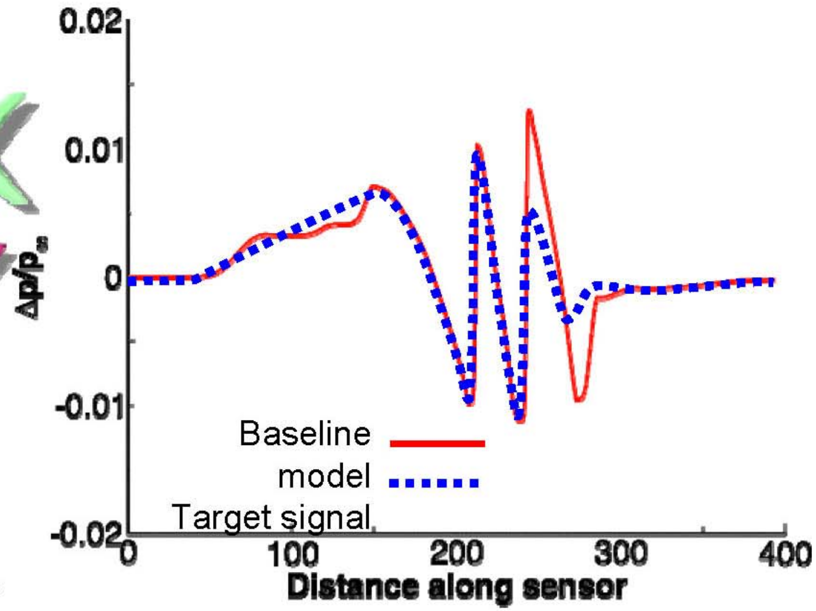
Proposed Initial Design



Final Design

FY 09 Technical Accomplishments





FY 09 Technical Accomplishments

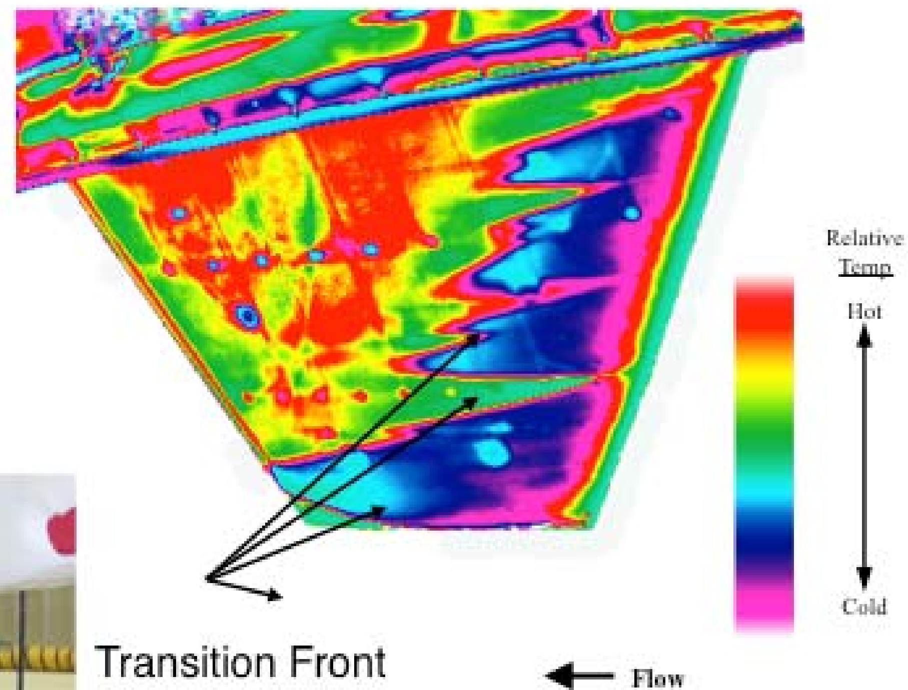
Ames model with single probes

Mast-mounted multi-port probe rail

Gulfstream model with wall-mounted multi-port probe rail

Gulfstream

FY 09 Technical Accomplishments



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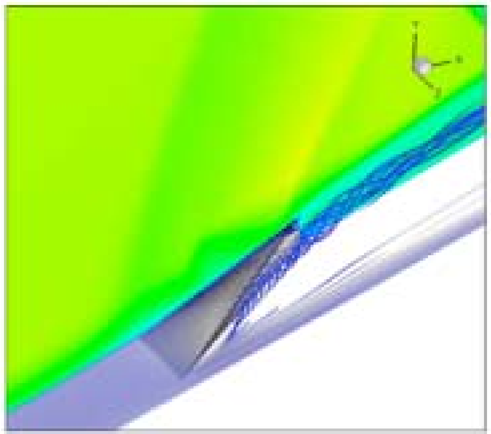
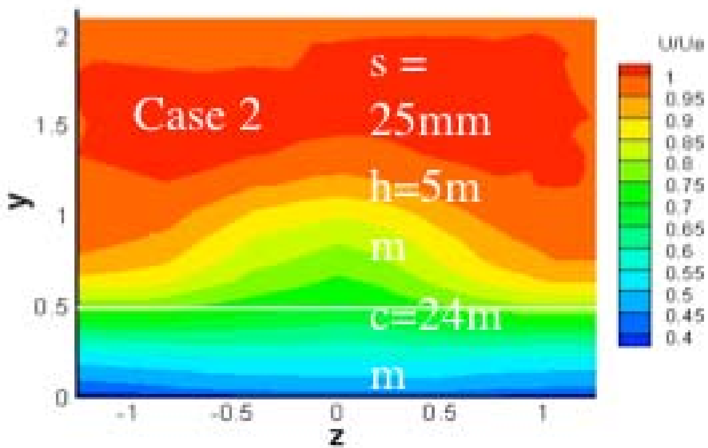
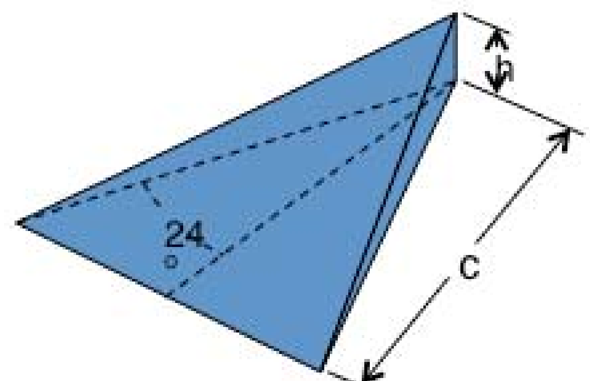
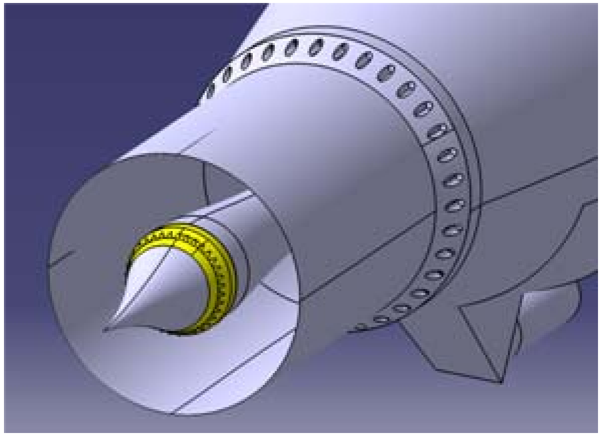


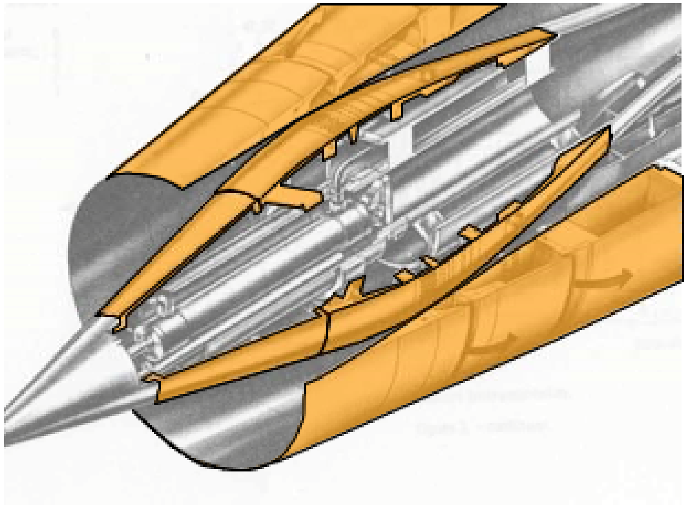




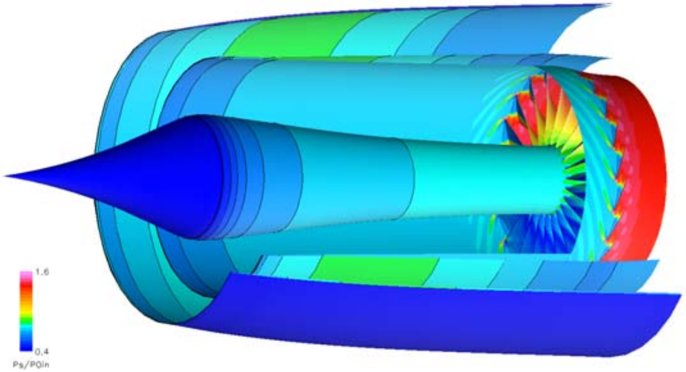
Micro-ramp flow control device

FY 09 Technical Accomplishments





40/60 Inlet - ***Redesigned Parts in Gold***



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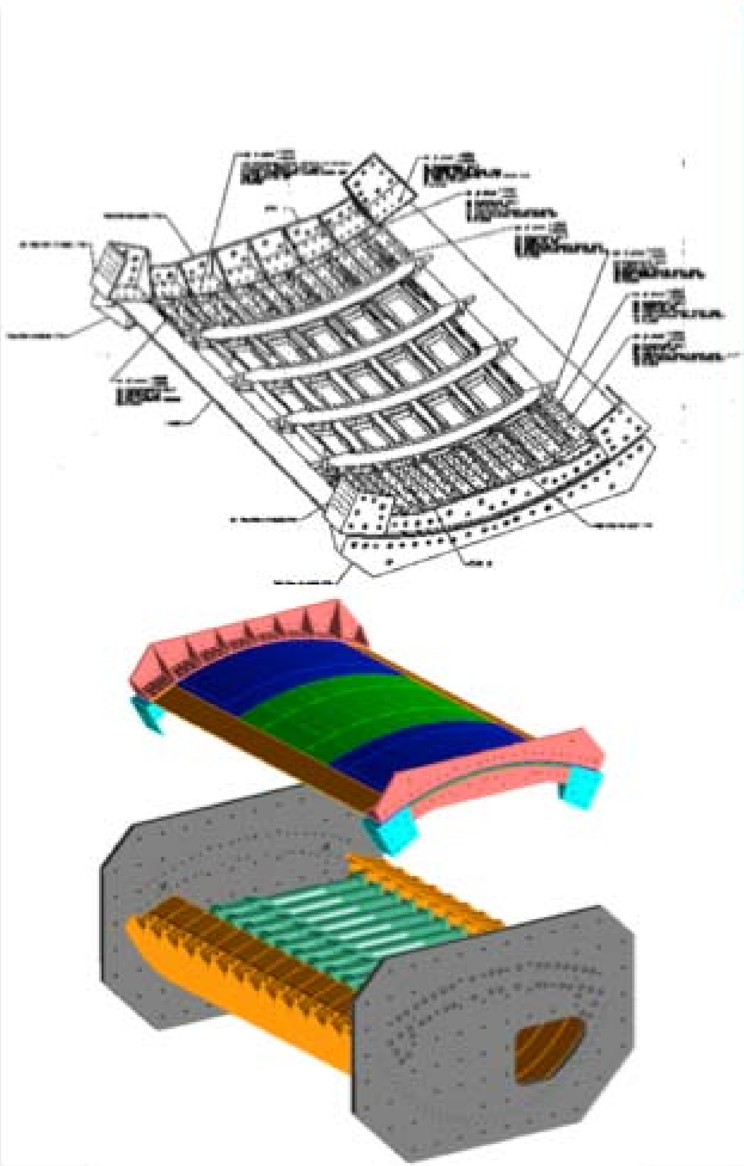

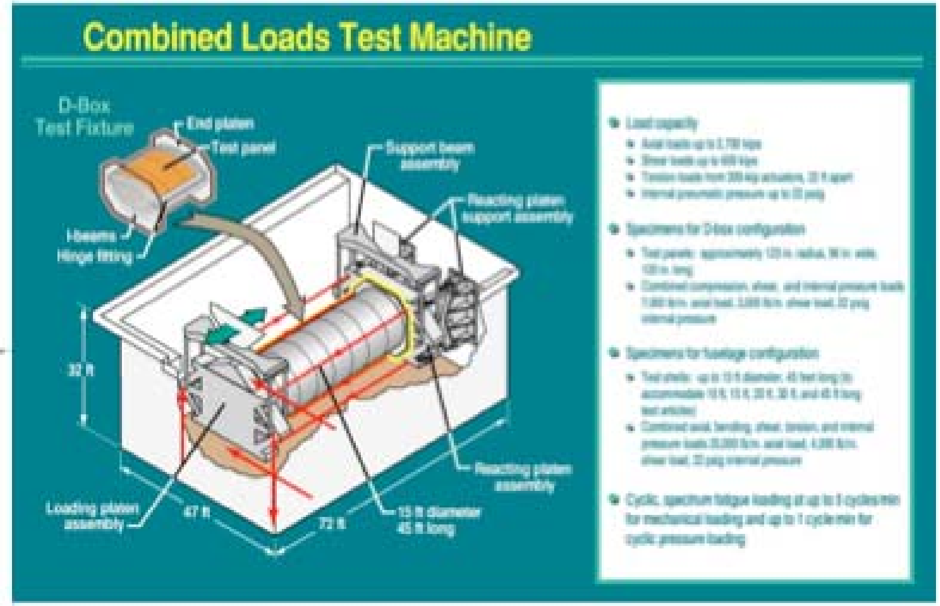

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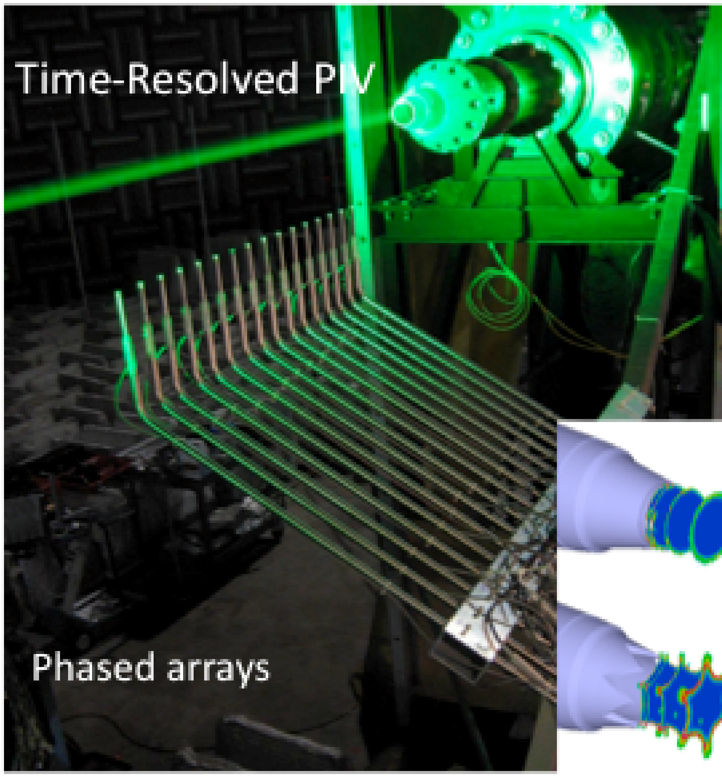

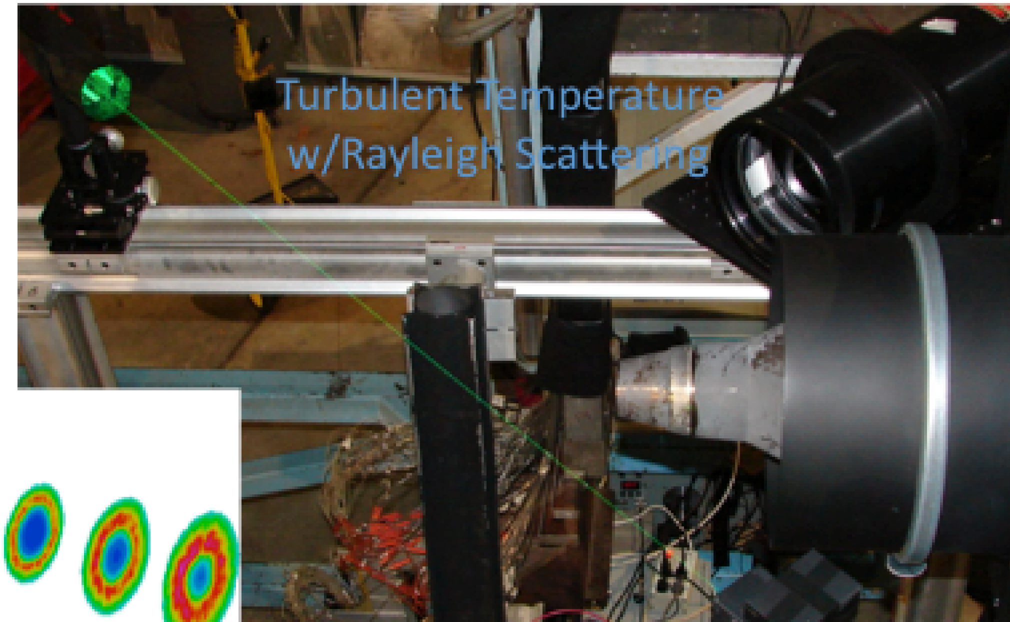

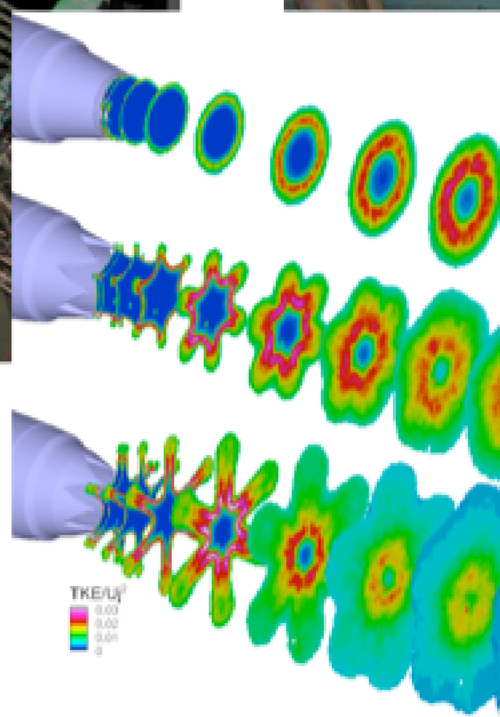

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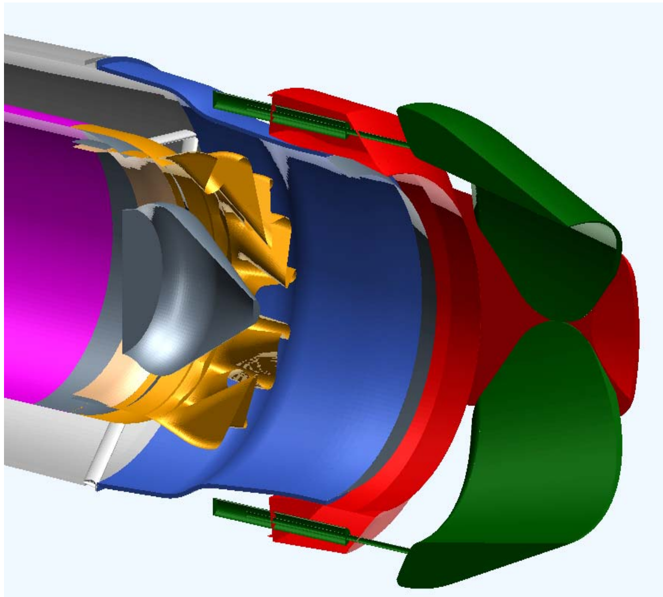
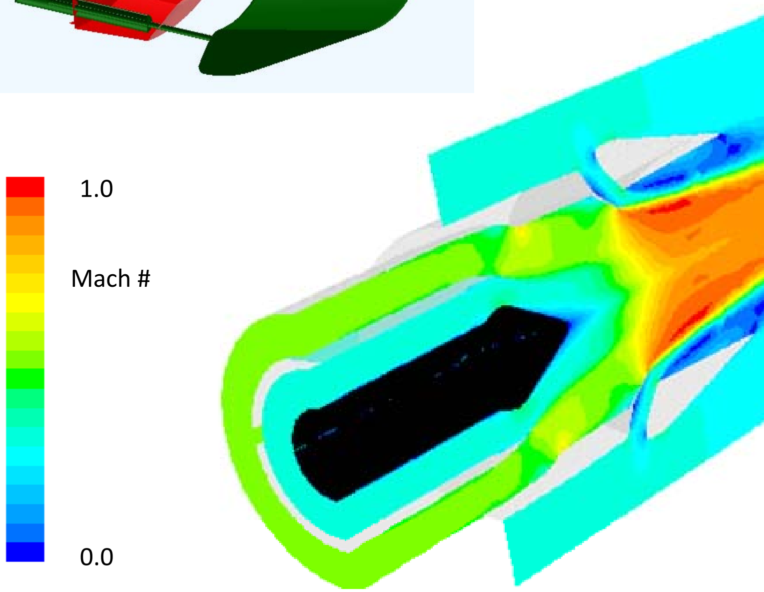


Take off Configuration



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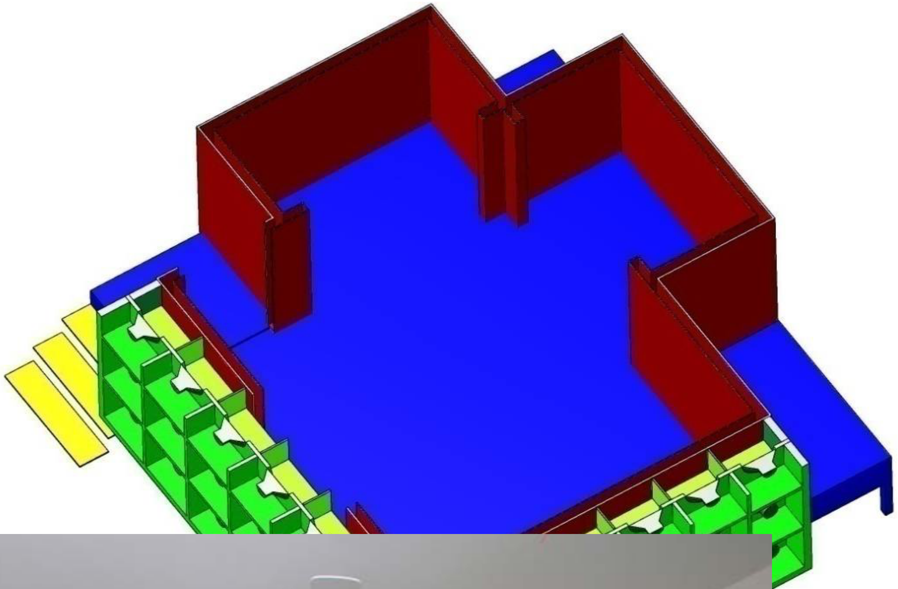

FY 09 Technical Accomplishments

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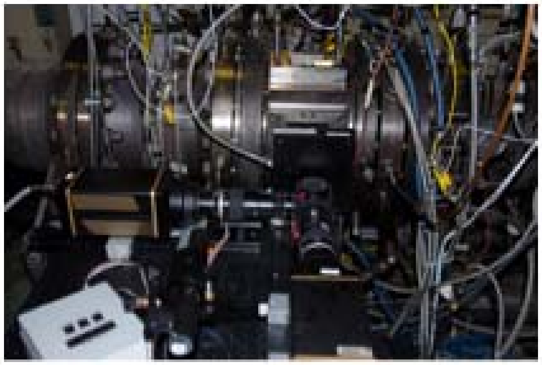
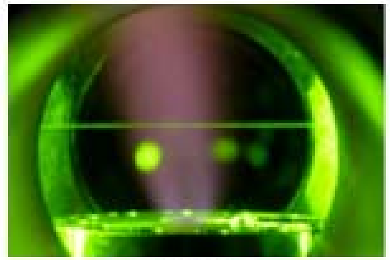


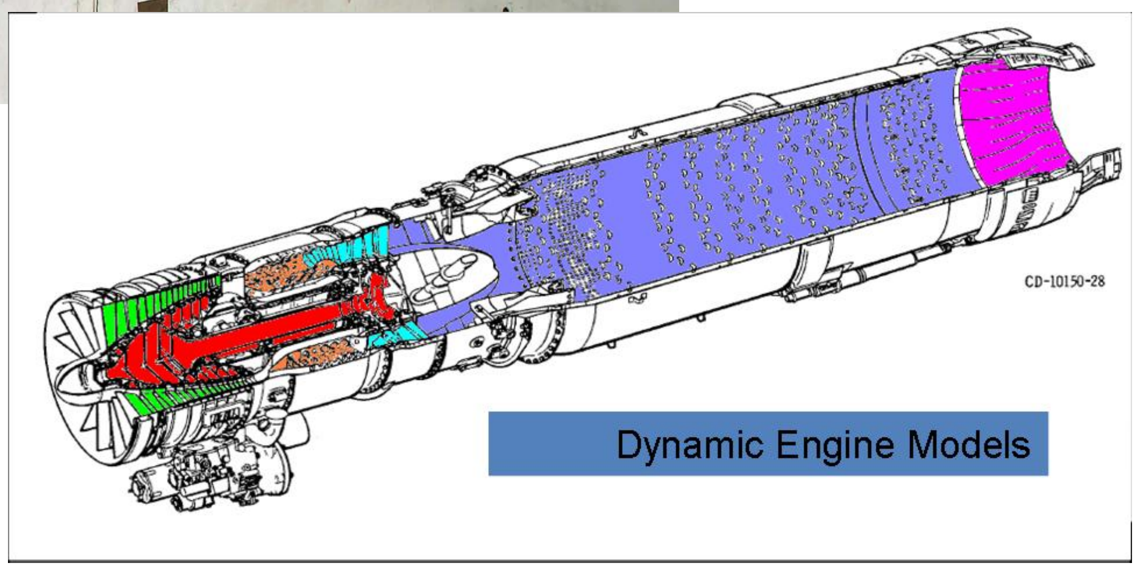
CE-5 High Pressure Flametube Stand 2



SE-5 High-Pressure Laboratory Scale Burner

SE-11 Particle Altitude Simulation Laboratory

FY 09 Technical Accomplishments



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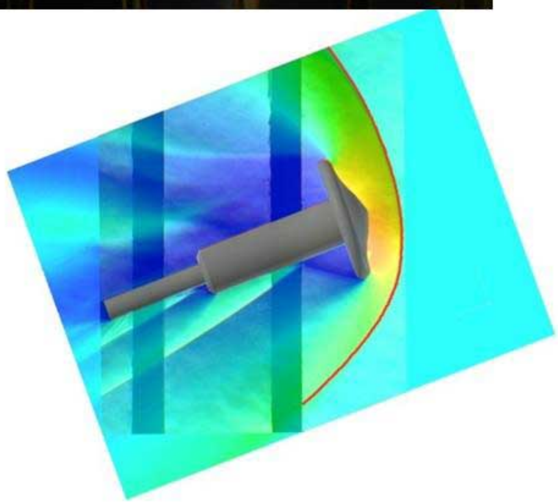
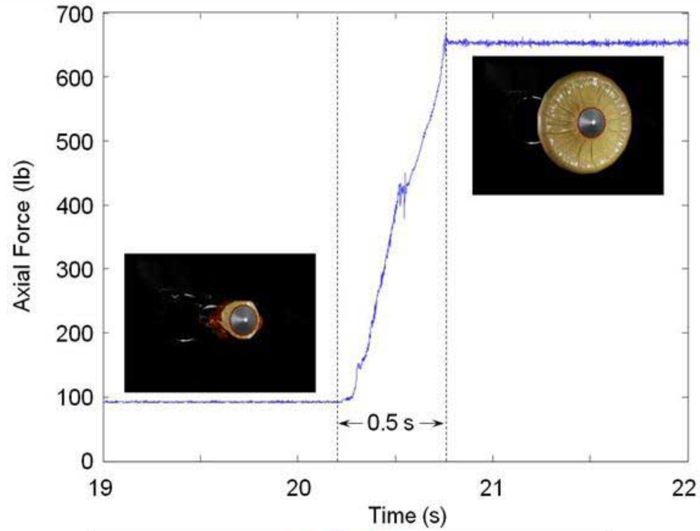
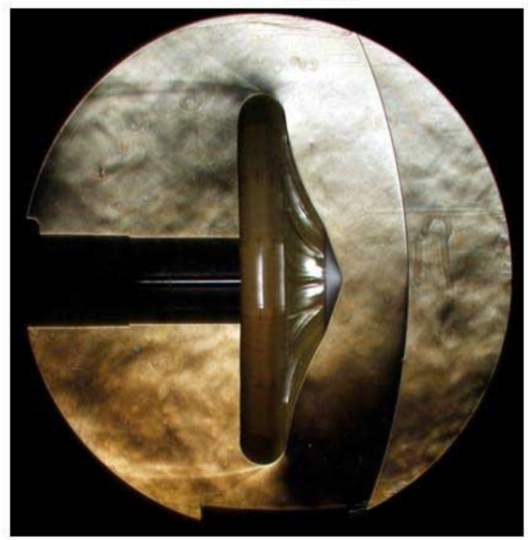






Many Thanks to the Whole Team!

NRA Status

- FY09 – 2 Solicitations
  - Low emissions combustor design and test hardware development (3 awards)
  - N+2 Technology Validations (2 awards in negotiation)
- FY10
  - Sonic Boom Modeling solicitation early FY10
  - Many earlier awards concluding
  - Desire maximum amount of competition in subsequent activities
  - Broad solicitation likely mid FY10

	Educational Institutions	Commercial Entities
Systems Integration & Assessment	2	5
Cruise Efficiency – Propulsion	3	3
Cruise Efficiency – Airframe	5	2
Lightweight & Durable Airframes	5	2
Lightweight & Durable Engines	6	2
Airport Noise	5	2
Sonic Boom Modeling	2	3
High Altitude Emissions	5	4
Aero-Propulso-Servo-Elasticity	0	2
Experimental Validations & Capabilities	0	1
Entry, Descent, & Landing	5	4
Total Awards	**38**	**30**

Total: 68 NRA Awards $43.4M values

Partnership Update

- **Gulfstream Aerospace** - Tool development and validation for integrated low boom/low drag aircraft design
  - External Vision System requirements validation study complete
  - New activity to identify the effect of rattle in sonic boom annoyance
- **Aerion Corporation** - Supersonic Boundary layer transition prediction and validation using the CLIP test fixture on F15B
  - Hardware on site at DFRC, first fight late fall?
- **FAA Office of Environment** – Cooperatively pursue research supporting sonic boom standards development
- **DoD Strategic Environmental Research and Development Program (SERDP) and NAVAIR** - Jet reduction concept development
  - Concepts, advanced diagnostic tools, and data from in house, NRA and SBIR activities are being shared with NAVAIR projects resulting in early exposure at higher TRL
  - Application of NASA advanced diagnostics in NAVAIR engine tests.
  - Technical review of DoD contractor activities
- **JAXA** – Fundamental supersonic technologies
  - Continued cooperation on structural-acoustic response to sonic boom
  - Cooperative agreement on supersonic boundary layer transition recently signed

Emerging Partnership Opportunity

Research Supporting Development of Standards for Community Exposure to Sonic Booms

- ICAO CAEP WG1 Supersonic Task Group (SSTG) is in the initial stages of developing a research roadmap
  - Identify research requirements that support development of sonic boom standards
  - Drafting group membership includes FAA, EASA, ICAS, DGAC, CNRS, NASA & Industry
- Roadmap covers the scope of activities related to community response
  - Metric development and validation
  - Effects of the atmosphere and flight operations
  - Community testing and extrapolation to broad populations

CAEP8_WG1_SSTG5_WP02
April 2009

ICAO Committee on Aviation Environmental Protection
Working Group 1: Aircraft Noise

Paris, France

23 April 2009

Roadmap on Research for Community Response to Sonic Boom

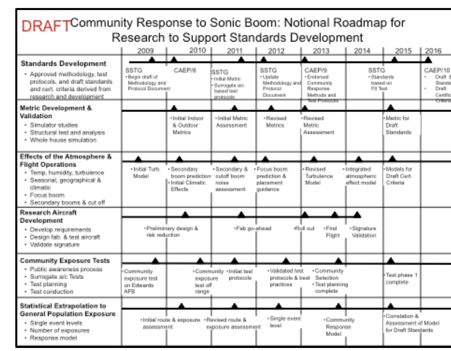
Presented by U.S. Representatives

On behalf on the Ad Hoc Group

SUMMARY

An Ad Hoc group was formed to participate in the development of a proposed roadmap for research into the perceived impact of sonic boom on the environment and communities. This working paper presents the Ad Hoc group's efforts in identifying key elements and notional chart of key elements that would be needed for this roadmap.

Recommend the Supersonic Transport Task Group (SSTG) review, discuss, and accept the key elements of the proposed roadmap and notional chart. Recommend SSTG approve and support an Ad Hoc Group to continue to further develop and finalize the roadmap.



- Research activities should be international and cooperative to as large as extent as possible.
- Recent Activity
  - Demonstration of low noise sonic booms for WG1 and SSTG at NASA DFRC
  - International workshop on technical details of roadmap

FY10 Directions

- Shift focus towards Sonic Boom Technical Challenge
  - Design for simultaneous achievement of low boom and low drag
    - Analytical tool and process development
    - Wind tunnel validation (FY 09 NRA)
  - Modeling of boom impact on structures, people
    - Simulation and flight activities
    - New NRA Solicitation (Early FY 10)
  - Continue to build international consensus on community response research
    - ICAO/CAEP roadmapping activities
  - Continue to explore approaches to large scale testing
- Continue robust effort in remaining Technical Challenges
  - Highlights
    - Advanced inlet and nozzle tests
    - Low NO_x combustor hardware development and testing
    - Large composite panel test to failure
    - New broad NRA solicitation (Mid FY 10)

Supersonics Technical Sessions

- Tuesday PM
  - Technology Challenge Overviews (15 minute presentations)
- Tuesday PM (concurrent session)
  - Advanced Vehicles in NextGen
- Wednesday AM
  - Aero-Propulso-Servo-Elasticity
  - Cruise Efficiency - Propulsion
  - Cruise Efficiency - Airframe
- Wednesday PM
  - Systems Integration, Assessment and Validation
  - Airport Noise
- Wednesday Evening
  - Student Session
    - University Design Competition for Supersonic Cruise Aircraft
      - Contest Winners
      - Intern Presentations
- Thursday AM
  - Sonic Boom Modeling
  - High Altitude Emissions
  - Feedback Session (Open Forum 1 hr)
- Thursday AM (concurrent session)
  - Supersonic Laminar Flow Roadmapping
- Thursday PM
  - Lightweight, Durable Airframes
  - Lightweight, Durable Engines
- Thursday PM (Hypersonics session)
  - Entry Descent and Landing Technologies

Thank You,

Welcome to the 2009 Fundamental Aeronautics Annual Meeting

Next Speaker:

Dr. Jim Pittman: Principal Investigator, Hypersonics Project